Xanthan Gum in a Reduced-Egg-White Angel Food Cake[1]

L. L. MILLER[2] and C. SETSER[3]

ABSTRACT

Xanthan gum is suggested as a replacement for certain ingredients in cake systems. Additions of 0.4% xanthan gum, 50% water, and/or 25% wheat starch, based on flour weight and in all possible combinations, were made to angel food cakes containing 65% total egg white. Analysis of variance of physical and sensory data revealed that the cakes differed significantly ($P \leq 0.05$) as a result of treatment. Xanthan gum increased foam stability, and wheat starch contributed to structure of cakes containing reduced egg white. Added water lowered egg-white surface tension, allowing greater air incorporation. Instrumental measurements of firmness and springiness and sensory analysis by a six-member, experienced panel (using a five-point category scale) indicated that cakes with 50% added water and 25% wheat starch were more similar to 100% egg-white cakes than were cakes in which xanthan gum was used alone or in combination with water and wheat starch.

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The cost of each ingredient in a given food must be carefully evaluated by the food processor with respect to current economic conditions. Opportunities are limited for adjusting formulations, yet bakers and food processors are being forced to consider alternatives for such functional, but costly, ingredients as eggs (Enochian and Saunders 1963, Voss 1963). The three basic ingredients in angel food cake are egg whites, sugar, and flour, of which egg whites are probably the most important functionally.

A manufacturer of xanthan gum proposed that xanthan gum can replace all or a portion of certain functional ingredients, such as eggs, in cake systems.[4] Christianson et al (1974) and Kulp et al (1974) used xanthan gum in starch breads, and Christianson (1976) hypothesized that gelatinized starch binds with xanthan gum to form a complex lattice-structured wall that retains gas. We used a 65% total egg-white level to study the effects of xanthan gum, wheat starch, and water on volume and textural properties of an angel food cake containing reduced egg white.

MATERIALS AND METHODS

Proposed AACC method 10-95 for testing baking quality of angel food cake flour (Kissell and Bean 1978) was modified for use in preparing test cakes. A commercial soft wheat patent cake flour containing 9.3% protein (N × 5.7), 0.54% ash, and 0.86% fat (14% moisture basis) was used throughout the study. Other ingredients and specifications are listed in Table I.

Xanthan gum was sifted with the first portion of sugar, acid salt, and sodium chloride before being added to the rehydrated egg whites. Wheat starch was sifted with the flour-sugar mixture and folded into the egg-white foam. Additional water, when used, was added to the rehydrated egg whites before they were beaten to a foam. A Hobart N-50 mixer (speed 1, 68 rpm; speed 2, 132 rpm; speed 3, 256 rpm) was used. Foam specific gravity was standardized at 0.14 ± 0.01. The flour-sugar mixture was incorporated into the foam by 29 strokes with a hand-held whip instead of a mixer. The bowl was turned one-quarter turn at each stroke, and the whip was brought up from the bottom of the bowl through the center of the foam every fourth stroke. Cakes were baked in a Reed Company gas-fired reel oven. After cooling for 90 min, they were wrapped loosely in the pan with plastic wrap and stored overnight at room temperature; then they were evaluated.

Preliminary work indicated that 65% total egg white and 0.4% xanthan gum (flour weight basis) could be used in further investigations of cakes with added water and/or wheat starch. A 20% egg-white reduction appeared to be possible without major formula adjustments, as physical measurements for these cakes were not significantly different from control cakes. A 50% egg-white reduction resulted in cakes significantly different from the 100% egg-white (control) cakes in every physical measurement. The 65% egg-white cake had some structure, as indicated by width measurements, that was not significantly different from that of the control cakes; but the standing height measurements for the 65% egg-white cakes were significantly lower than for the control cakes. We established that 50% additional water and 25% wheat starch (flour weight basis) were beneficial in producing cakes with good structure. For the 65% egg-white cakes, amounts of all ingredients were increased by 25% to ensure enough batter.

Specific gravity of batter, batter pH, foam stability (as indicated by foam drainage), standing height of cakes (as an index of volume both in and out of the pan), and width of cakes (as an indication of shrinkage) were measured. The Instron Universal testing machine, model 1122, was used to evaluate crumb firmness and springiness. Using the 50-cm^2 compression anvil A372-17 with the 500-kg load cell, 2.5-cm cubes taken from the midsection of the cakes were compressed to 1.0 cm (40% compressibility ratio) with a 0.2-kg scale load. Sensory analysis of the cakes was by a six-member panel trained to evaluate (using five-point category scales) contour, grain, cell walls, crumb tenderness, elasticity, sweetness, and moisture absorption. Three samples were evaluated at each session. A randomized complete block design, plus a control cake, was used. Data for the nine treatments and three replications were subjected to analysis of variance; least-squares means were compared to determine treatment effects.

TABLE I
Formulation (Based on Flour) for an Angel Food Cake

Ingredient	Control Cake (%)	65% Egg-White Cake (%)
Flour, bleached, soft-wheat patent (Sno Sheen, Pillsbury)	100.0	100.0
Sugar, baker's special (Domino, Amstar)	285.00	185.00
Rehydrated egg albumen[a] (Type P-20, Henningsen)	305.0	198.0
Acid salt, monocalcium phosphate monohydrate (Reagent 12XX, Stauffer Chemical Co.)	1.4	1.4
Sodium chloride	2.7	2.7
Additional water	···	50.0
Xanthan gum (Keltrol F, Kelco Co.)	···	0.4
Wheat starch, unmodified (Paygel P, General Mills[b])	···	25.0

[a]12% solids to 88% distilled water.
[b]Now available from Henkel Laboratories.

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[2]Present address: Thomas J. Lipton, Inc., Englewood Cliffs, NJ 07632.
[3]Graduate research assistant and associate professor, respectively, Department of Foods and Nutrition, Kansas State University, Manhattan.
[4]Kelco Company, San Diego, CA. Personal communication.

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RESULTS AND DISCUSSION

Least square means for physical measurements are compared in Table II and for sensory characteristics in Table III.

Adding water to a 65% egg-white cake lowers surface tension of the egg white so that more air can be incorporated into the batter (le Clerc and Bailey 1941), as was evidenced in the lowered ($P \leq 0.05$) batter-specific gravity of those cakes with added water. Air incorporated into the batter was not always held, however: foams with only added water were significantly less stable than foams of the 65% egg-white cake without added water or xanthan gum, or foams of the reduced-egg-white cakes with added water in the presence of xanthan gum. The protein films were weakened (diluted) because water alone is not viscous enough to prevent drainage from the air bubbles of the foam (Baldwin 1973). Xanthan gum and wheat starch are both hydrophilic colloids, and thus would be expected to increase viscosity of a water system. With wheat starch, however, viscosity increase occurs mainly during gelatinization with heating; xanthan gum, being both hot- and cold-water soluble, exhibits high viscosity at low concentrations both before and after heating (Anonymous 1974, 1978; Hodge and Osman 1976; Rocks 1971).[5] In this study, the presence or absence of starch in the reduced-egg-white cake with added water made no significant differences in the cake's foam stability (Table II).

Foam instability was further evident in the increased shrinkage or decreased width ($P \leq 0.05$) of the reduced-egg-white cakes with added water without starch. When the batter was heated, the air bubbles in the foam expanded, but leavening power was lost because the nonelastic film containing the air bubbles was unable to expand (Baldwin 1973). Cakes collapsed, resulting in a significantly firmer cake crumb with thicker ($P \leq 0.05$) cell walls (Table II).

Adding water was structurally beneficial in the reduced-egg-white cakes when xanthan gum or wheat starch was present. Cake contour was significantly more symmetrical when water was added in the presence of either or both hydrophilic colloids. Wheat starch appeared to be more effective than xanthan gum in improving standing height of the 65% egg-white cake with added water; standing height outside the pan was not significantly different from that of the 100% egg-white control cake. Also, no significant differences in width were found when wheat starch was present and water was added; but if xanthan gum, or xanthan gum and wheat starch were present and water was added, widths were significantly decreased, indicating greater shrinkage during baking. Christianson (1976) reported that increased moisture was needed in xanthan gum-starch breads to fully hydrate the starch and the gum. Because xanthan gum and wheat starch are both hydrophilic and compete for available water, the water level in our study might not have been sufficient to fully hydrate both additives in the 65% egg-white cake. Cakes were structurally improved when wheat starch was added with sufficient hydration to gelatinize during baking, but the detrimental effect that resulted when both xanthan gum and wheat starch were present indicate insufficient water for

[5] From Merezan, Xanthan gum for the food industry. Bulletin G-34, Meer Corp., North Bergen, NJ.

TABLE II
Physical Measurements of Angel Food Cakes Containing 65% Egg White[a] With and Without Xanthan Gum, Water, and Wheat Starch Compared[b] With 100% Egg-White Cakes

Physical Measurement	100% Egg-White Control	Wheat Starch (%) 0 at 0% H_2O at 0 XG[c]	0 at 0% H_2O at 0.4 XG	0 at 50% H_2O at 0 XG	0 at 50% H_2O at 0.4 XG	25 at 0% H_2O at 0 XG	25 at 0% H_2O at 0.4 XG	25 at 50% H_2O at 0 XG	25 at 50% H_2O at 0.4 XG
Batter specific gravity	0.263 a	0.317 bcd	0.320 cd	0.287 ab	0.283 a	0.343 d	0.327 d	0.283 ab	0.290 abc
Batter pH	5.47 b	5.22 a	5.27 a	5.16 a	5.20 a	5.21 a	5.22 a	5.21 a	5.19 a
Foam stability (drainage, g)	29.20 c	6.18 a	1.47 a	19.37 b	1.47 a	3.63 a	0.17 a	18.77 b	1.07 a
Standing height									
In pan (cm)	6.92 f	4.73 bc	4.17 ab	4.26 ab	3.90 a	5.45 de	5.23 cd	6.11 e	4.63 bc
Out of pan (cm)	6.31 e	4.37 abc	4.01 ab	4.11 ab	3.81 a	4.94 d	4.83 cd	5.78 e	4.43 bcd
Width (cm)	9.24 d	8.46 c	8.17 bc	7.64 a	7.35 a	8.60 c	8.60 c	8.54 c	7.70 ab
Firmness (kg)	0.17 a	0.57 ab	1.03 cd	1.47 de	1.87 a	0.50 ab	0.77 bc	0.47 ab	1.43 de
Springiness	8.0 bc	8.3 bc	7.0 ab	7.0 ab	6.0 a	8.0 bc	8.3 bc	8.7 c	7.3 ab

[a] Flour-weight basis.
[b] Means in a row with same letter do not differ significantly ($P \leq 0.05$). Least squares means from three replications.
[c] Percent xanthan gum.

TABLE III
Sensory Characteristics of Angel Food Cakes Containing 65% Egg White[a] With and Without Xanthan Gum, Water, and Wheat Starch Compared[b] With 100% Egg-White Cakes

Sensory Characteristic[c]	100% Egg-White Control	Wheat Starch (%) 0 at 0% H_2O at 0 XG[d]	0 at 0% H_2O at 0.4 XG	0 at 50% H_2O at 0 XG	0 at 50% H_2O at 0.4 XG	25 at 0% H_2O at 0 XG	25 at 0% H_2O at 0.4 XG	25 at 50% H_2O at 0 XG	25 at 50% H_2O at 0.4 XG
Contour	3.61 de	2.03 ab	1.58 a	2.47 bc	3.06 cd	2.67 bc	2.39 b	3.94 e	3.58 de
Grain	3.92 d	1.89 b	1.33 a	1.94 b	1.56 ab	2.72 c	2.61 c	3.69 d	2.61 c
Cell walls	3.39 d	2.69 bc	1.92 a	1.97 a	1.47 a	2.81 bc	2.58 b	3.19 cd	2.75 bc
Crumb tenderness	3.08 ab	3.11 abc	2.78 a	2.61 a	2.64 a	3.67 cd	3.86 d	3.50 bcd	3.56 bcd
Elasticity	3.72 d	2.61 ab	2.00 a	2.58 ab	2.08 a	3.08 bc	3.53 cd	3.69 cd	3.17 bcd
Sweetness	2.61 a	3.17 b	3.17 b	2.67 a	2.69 ab	2.47 a	2.39 a	2.58 a	2.39 a
Moisture adsorption	3.14 bc	2.89 b	2.06 a	2.22 a	2.25 a	3.94 d	3.86 d	3.72 cd	3.42 bcd

[a] Flour-weight basis.
[b] Means in a row with same letter do not differ significantly ($P \leq 0.05$). Least squares means from three replications.
[c] Scale used was 1–5, with 5 representing the ideal for contour and grain; 3, ideal for crumb tenderness, sweetness, and moisture adsorption; and 4, ideal for cell walls and elasticity.
[d] Percent xanthan gum.

complete hydration of both.

Christianson (1976) has suggested that a xanthan gum-starch complex forms to retain gas during baking of starch breads. A lack of evidence of such a complex in our reduced-egg-white cakes may also be related to insufficient water. Further work would be desirable with xanthan dissolved in water before its addition to the egg white to ensure its hydration and to enhance the effect of xanthan gum on foam stability.

Xanthan gum without added water appeared ineffective in the reduced-egg-white cakes, resulting in a significantly firmer cake crumb (Table II), more collapsed grain, and thicker cell walls (Table III). Xanthan gum seemingly competes for available water at the expense of the structure formers, proteins and starch, resulting in a collapsed structure during baking. No significant differences in physical measurements or sensory characteristics were found when xanthan gum was added in the presence of wheat starch.

Wheat starch alone added to the reduced-egg-white cakes significantly increased standing height (Table II), the grain was more open, and the cakes were less tender than control cakes (Table III). Wheat starch with added water resulted in a cake with similar physical and sensory characteristics to the control cake. Although removing 35% egg white did decrease ($P \leq 0.05$) pH, foam stability was improved significantly. Standing height in the pan and width measurements were significantly lower than those of the 100% egg-white cake, but no significant differences in standing height out of the pan were found (Table II). The importance of starch gelatinization and the extent to which it occurs in angel food cake has been reported (Hoseney et al 1977, 1978; Lineback and Wongsrikasen 1980). Derby et al (1975) and Hoseney et al (1977) emphasized that temperature, available water, and other ingredients present in the system are important in determining the extent of gelatinization. Derby et al (1975) suggested that the differences in moisture content that affect starch gelatinization also influence product volume. Based on our results, it would seem possible to restore volume equal to that of the 100% egg-white control cake, provided levels of ingredients were optimum. The cake with 50% added water and 25% wheat starch did not differ significantly from the 100% egg-white control for any sensory measurement.

CONCLUSIONS

Egg white is a polyfunctional ingredient, and its foaming and coagulating abilities are particularly important functions in the production of angel food cake. An angel food cake containing 35% less egg white than normally used differs significantly from the 100% egg-white control cake. Adding xanthan gum, water, and wheat starch improves the reduced egg white cake, and one ingredient may be more beneficial at one time than at another. Added water is important in lowering surface tension of the egg white so that more air can be incorporated into the reduced egg-white batters. Xanthan gum enhances foam stability by holding the added water in the foam. Wheat starch contributes to structure by gelatinization during baking. Based on results of this study, no one of the added ingredients—xanthan gum, water, or wheat starch—can successfully replace 35% of the egg white in angel food cake. However, the reduced-egg-white cake made with wheat starch and added water will be similar to the 100% egg-white (control) cake.

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